# 8 Blue shark in the North Atlantic (North of 5ºN)

## 8.1 Stock distribution

There is a discrete North Atlantic stock of blue shark *Prionace glauca* (Heessen, 2003; Fitzmaurice *et al*., 2005; ICCAT, 2008), with 5°N latitude as the southern stock boundary, and a separate South Atlantic stock (ICCAT, 2008). This delineation is based on mark-recapture data and oceanographic features. In addition, this division facilitates comparison with fisheries statistics of other North Atlantic stocks, such as tuna-like species, that have the same southern stock boundary. Hence, the ICES area is only part of the stock area.

Recent genetic studies on blue shark reveal genetic homogeneity across whole ocean basins in Atlantic (Verissimo *et al*., 2017) and Pacific oceans (Ovenden *et al*., 2009; Taguchi *et al*., 2015). These are at odds with the currently assumed distinction of northern and southern stocks within each ocean basin. The bulk of the evidence gathered thus far indicates that the blue shark exhibits dispersal with gene flow over very large spatial scales, and little to no philopatry to the sampled nursery areas or to distinct ocean basins. However, in cases as in blue sharks where effective populations sizes are ~1000s, the levels of genetic divergence associated with migration rates which could lead to demographic connectivity (~10%; Hastings, 1993) may be difficult to detect using traditional molecular markers. In these cases, the precautionary approach in conservation and fisheries management would be to consider each nursery area as independent, with potentially different demographic parameters and vulnerability to fishing pressure. If each nursery area currently exchanges only a few migrant individuals per generation with other nurseries, the replenishment of each stock would be mostly dependent on recruit survival rather than on immigration from adjacent stocks.

## 8.2 The fishery

### 8.2.1 History of the fishery

In recent years, more information has become available about fisheries taking blue shark in the North Atlantic. Although available data are incomplete, they offer information on the situation in fisheries and trends. There are no large-scale target fisheries for blue shark, but it is a major bycatch in tuna and billfish fisheries, where it can comprise up to 70% of the total catches and even exceed the catch of target species (ICCAT, 2005). In the North Atlantic, EU fleets (Portugal and Spain) are responsible for approximately 82% of the total landings (Anon., 2015).

Observer data indicates that substantially more blue sharks are caught as bycatch than reported in landings statistics. Blue sharks are also caught, in considerable numbers, in recreational fisheries, including in the ICES area (Campana *et al*., 2005).

Since 1998, there has been a Basque artisanal longline fishery targeting blue shark and other pelagic sharks in the Bay of Biscay from June to November (Díez *et al*., 2007). Initially 3–5 vessels were involved but, as a consequence of changes in local fishing regulations, the number of vessels has reduced to two after 2008.

In the North Atlantic, thirteen fisheries (in descending order of volume: EU-Spain, EU-Portugal, Japan, Canada, USA_LL, Chinese Taipei, EU-France, Belize, Panama, USA_SP., China PR, Korea and, Venezuela) accounted for 99% of the total removals (1990–2014). The majority (except: USA sport fishery, EU-France unclassified gear) are longline fisheries (Anon., 2015). There are also blue shark landings in Mediterranean fisheries (Anon., 2015).

In 2015, prior to their most recent stock assessment, ICCAT nominal catch statistics of blue shark (by stock, flag and gear) were reviewed. No major updates were made to the historical catch series, and only recent years of official catches were updated. Before 1997, there was a lack of official catch statistics for some of the main fishing nations operating in the stock area.

### 8.2.2 The fishery in 2020

No new information.

No major changes noted in 2020, although potential changes to fishing effort caused by the effects of COVID-19 have not yet been quantified.

### 8.2.3 Advice applicable

ACOM has never provided advice for blue shark in the ICES area. Assessment of this stock is considered to be the responsibility of ICCAT. In July 2015, members of WGEF participated in the ICCAT blue shark stock assessment meeting that took place in Lisbon, Portugal (ICCAT, 2015).

In 2015, ICCAT considered that the status of the North Atlantic stock is unlikely to be either overfished or subject to overfishing. However, due to the level of uncertainty in the assessment results no specific management recommendations were provided (ICCAT, 2015).

ICCAT adopted Rec. 16-12, which in paragraph 2 establishes a catch limit for blue sharks in the North Atlantic (39,102 t as the average of two consecutive years). This measure came into being in 2017 and the Standing Committee on Research and Statistics (SCRS) has been in a position to assess the effect of this measure as yet. However, SCRS data show that preliminary catches in 2017 and 2018 were 39 675 t and 33 853 t, respectively (SCRS, 2019).

In 2019, these catch limits were further refined when ICCAT adopted Rec. 19-07. This states that: "*An annual TAC of 39 102 t for North Atlantic blue shark is established. The annual TAC may be revised subject to a decision of the Commission based on the updated advice of the SCRS in 2021, or at an earlier stage if enough information is provided by the SCRS*". Catch limits for the EU, Japan and Morocco were set at 32 578 t, 4 010 t and 1 644 t, respectively, with all other CPCs to "*endeavour to maintain their catches at recent levels*".

### 8.2.4 Management applicable

There are no measures fully regulating all the catches of blue shark in the North Atlantic.

European regulations for annual fishing opportunities have given an overall TAC (39 102 t) for blue shark in the Atlantic Ocean north of 5°N since 2017. Whilst this nominal TAC has remained unchanged, an allocation key was included in the 2020 fishing opportunities (Council Regulation (EU) 2020/123), under which the EU quota was set at 32 578 t (83.3% of the 39 102 t TAC, and in accordance with ICCAT Rec. 19-07), and this was allotted to Spain (27 062 t), Portugal (5 363 t), France (152 t) and Ireland (1 t).

EC Regulation No. 1185/2003 (updated by EU Regulation No 605/2013) prohibits the removal of shark fins of these species, and subsequent discarding of the body. This regulation is binding on EC vessels in all waters and non-EC vessels in Community waters.

## 8.3 Catch data

### 8.3.1 Landings

It is difficult to accurately quantify landings of blue shark in the North Atlantic. Data are incomplete, and the generic reporting of shark catches has resulted in underestimations. Landing data from different sources (ICCAT, FAO and national statistics) can vary (Figures 8.1–8.3). Table 8.1 gives the catch data (total landings and discards by stock, flag and major gears) collated by ICCAT, which appears to provide the most complete catch data for this stock, though there can be small changes in these data over time (Tables 8.2–8.3). ICCAT considers that reported landings of blue shark were underestimated in the early part of the time-series (prior to 1997), with official landings and estimates of a comparable magnitude since 1997, when annual landings have been *ca.* 20 000–40 000 t. In the North Atlantic, blue shark is reported predominantly by Spain, Portugal, Japan, USA and Canada (Figure 8.1).

In 2015, alternative approaches to estimate catch series were discussed by ICCAT (Anon., 2015), including (i) ratios between blue shark catches and species-specific catches derived from ICCAT Task I data; (ii) catch/effort and standardised CPUE; and (iii) shark fin trade data. Figure 8.4 shows the catch series (1971–2013) for North Atlantic blue shark available for the 2015 stock assessment (SA2015), the 2008 stock assessment catches (SA2008), and the catch series obtained using shark-fin ratios (three different series, see for example Clarke *et al.,* 2006). Both stock assessment series followed a similar trend (but with large differences in some years) with catches oscillating several times between 15 000 t and 55 000 t. The three shark-fin series showed completely different trends (continuous upward trend) with catches starting around 10 000 t in the 1980s and growing to nearly 60 000 t in 2011 (Anon., 2015). Generally, the overall data for blue shark (and sharks in general) reported to ICCAT has improved over time (more complete series by species, lesser quantities of unclassified sharks, less weight of unclassified gears in the shark series, etc.). However, many unclassified shark species, mostly grouped by family (e.g. Lamnidae, Carcharhinidae, Sphyrnidae) and genera (e.g. *Rhizoprionodon, Carcharhinus, Sphyrna* and *Alopias* spp.) were reported to ICCAT in the past. The largest portion of unclassified sharks (1982–2013) is concentrated in longline and gillnet fisheries (Anon., 2015).

Japanese catches (landings and discards) from tuna longliners in the North Atlantic are estimated to have fluctuated between 1 400–2 400 t in 2006–2014, but a large increase to about 8 200 t is observed in 2015. These are higher than reported landings of the target species (bluefin tuna) from Japanese longliners in this period (ICCAT, 2008). Another study of Japanese bluefin tuna longline fisheries showed that the ratio of blue shark to the target species was about 1:1 (Boyd, 2008). Data from observations onboard a Chinese Taipei (Taiwanese) vessel targeting bluefin tuna in the southern North Atlantic showed that blue shark accounted for 76% of shark bycatch, though no information was presented on the percentage of blue shark in the total catch (Dai and Jang, 2008). Together, blue shark and shortfin mako account for between 69% and 72% of catches from Spanish and Portuguese surface longliners in the North Atlantic (Oceana, 2008).

The most recent ICCAT data publicly available for Task 1 data (landings and dead discards) for blue shark from the North Atlantic indicated a decrease in 2017–2019 (though 2019 data may be incomplete) compared to 2016 (Table 8.3). This would imply a reduction in landings in line with the ICCAT Recommendations relating to catch limits (see Section 8.2.3).

## 8.3.2 Discards

Historically, the relative low value of blue shark meant that it was not always retained for the market, with the fins the most valuable body part. In some fisheries the fins were retained and the carcasses discarded. In 2013, EU prohibited this practice (see Section 8.2.4).

Accurate estimates of discarding are required to quantify total removals from the stock. Currently no such estimates are available. Differences between estimated and reported catch in various fisheries (ICCAT, 2008 and references cited therein) suggest that discarding is widespread in fisheries taking blue shark.

Discard estimates are available for fisheries from Chinese Taipei, Korea Rep., USA, and UK (Bermuda) in recent years and from 2000 onwards from USA. However, they represent a limited part of total discards. The full extent of blue shark bycatch cannot be assessed using the data available, but evidence suggests that longline operations can catch more blue sharks than target species. There is considerable bycatch of blue sharks in Japanese and Taiwanese tuna longliners operating in the Atlantic. However, it is not possible, to estimate discard rates from these fleets from the information available. Discards can be assumed to be far higher than reported (Campana *et al*., 2005), especially in high seas fisheries.

Information on elasmobranchs discards in demersal otter trawl, deep-water set longlines, set gillnet and trammel net fisheries for ICES Division 9.a (2004–2013) showed that blue shark was caught infrequently and discarded in the longline fishery but not in the other fisheries (Prista *et al*., 2014).

## 8.3.3 Discard survival

Blue shark is one of the most frequent shark species captured in pelagic longline fisheries, and there are several estimates of survival (Boggs, 1992; Francis *et al*., 2001; Campana *et al*., 2005; Diez and Serafy, 2005). It is thought that most discards of whole sharks would be alive on return to the sea. For instance, discard survival rate is estimated to be about 60% in longline fisheries and 80% in rod and reel fisheries (Campana *et al*., 2005). More generally, the at-vessel mortality of longline-caught blue shark ranges from about 5–35% (summarised in Ellis *et al*., 2014 WD). Discard survival in such fisheries can be influenced by several factors, including hook type, soak time and size of shark. However, discarding can increase overall mortality attributable to fisheries: a study conducted on Canadian pelagic longliners targeting swordfish in the Northwest Atlantic (Campana *et al*., 2009) showed that "*overall blue shark bycatch mortality in the pelagic longline fishery was estimated at 35%, while the estimated discard mortality for sharks that were released alive was 19%. The annual blue shark catch in the North Atlantic was estimated at about 84 000 t, of which 57 000 t is discarded. A preliminary estimate of 20 000 t of annual dead discards for North Atlantic blue sharks is similar to that of the reported nominal catch, and could substantially change the perception of population health if incorporated into a population-level stock assessment*". The survival rate at hauling for blue shark was estimated to be 49% for the French pelagic longliners targeting swordfish in the southwest Indian Ocean. Field trials conducted with gears equipped with hook timers indicated that 29% were alive 8 h after their capture (Poisson *et al*., 2010). The survival rate of blue shark (at haul back) after a night-time soak may be lower than that during day-time soaks.

## 8.3.4 Quality of catch data

Catch data are incomplete, and the extent of finning in high seas fisheries is unclear. The historical use of generic shark categories is also problematic, although European countries now report more species-specific data.

In 2012, the ICCAT Secretariat noted some large discrepancies between the data in the EUROSTAT database and that of the ICCAT database, with EUROSTAT records showing captures almost double those of ICCAT in recent years.

Methods developed to identify shark species from fins (Sebastian *et al*., 2008; Holmes *et al*., 2009) could help to gather data on species targeted by illegal fishers, this information will greatly assist in management and conservation.

The variability of blue shark mortality estimates, relating to the proportion of live discards, hampers the estimation of total removals, although there are improving approaches to reporting of live discards to the ICCAT SCRS (Anon., 2015).

Given the uncertainty on the 2015 assessment of blue shark North Atlantic stock, ICCAT recommended continued monitoring of the fisheries by observer and port sampling programmes (ICCAT, 2015).

# 8.4 Commercial catch composition

No new information.

## 8.4.1 Conversion factors

Information on the length–weight relationship is available from several scientific studies (Table 8.4), as are the relationships between various length measurements (Table 8.5a and 8.5b). Campana *et al*., 2005 calculated the conversion relationships between dressed weight ($W_D$) and live weight or round weight ($W_R$) for NW Atlantic blue shark (n = 17) to be $W_R = 0.4 + 1.22\ W_D$ and $W_D = 0.2 + 0.81\ W_R$.

For French fisheries, the proportion of gutted fish to round weight is 75.19%. There is also a factor for landed round weight to live weight (96.15%), meaning that there is a 4% reduction in weight because of lost moisture (Hareide *et al*., 2007). Various estimates of fin weight to body weight are available (Mejuto and García-Cortés, 2004; Santos and Garcia, 2005; Hareide *et al*., 2007; Santana-Garcon *et al*., 2012; Biery and Pauly, 2012).

# 8.5 Commercial catch and effort data

For the North Atlantic stock, reported catches showed an increase in 1998, followed by a gradual decline until 2002 and then an increase (Figure 8.3). The CPUE input data available were comprehensively described and presented in the 2015 blue shark data preparatory meeting report (Anon., 2015). Following the work conducted for the 2008 SCRS blue shark stock assessment, CPUE were combined through a GLM with two choices of weighting: by the catch of the flag represented by each index and by the area of the flag represented by each index. Additionally, a hierarchical index of abundance that combines all available indices into a single series was also developed. However, it was noted that the process of combining CPUE indices was discouraged as they tend to mask the individual trends of the series and the underlying reasons as to why the series are different. It also indicated that some models can stochastically make use of the different series without need to combine these indices. It was suggested that it may be more useful to group CPUEs according to similar trends, and to include these as separate scenarios as was discussed during the 2015 bigeye tuna assessment.

Table 8.6 shows the various CPUE indices currently available (EU-Portugal, EU-Spain, USA, Japan, Chinese Taipei, and Venezuela), which have been considered for use in the assessment.

These CPUE indices show a relatively flat trend throughout the time-series, but with high variance (Tables 8.6–8.7; Figure 8.5).

## 8.6 Fishery-independent surveys

No fishery-independent data are available for the NE Atlantic, although such data exist for parts of the NW Atlantic (Hueter *et al.*, 2008). A survey from 1977–1994 conducted by the US NMFS documented a decline among juvenile male blue sharks by 80%, but not among juvenile females, which also occur in fewer numbers in the area, the western North Atlantic off the coast of Massachusetts (Hueter *et al.*, 2008). The authors concluded that vulnerability to overfishing in blue sharks is present despite their enhanced levels of fecundity relative to other carcharhinid sharks.

## 8.7 Life-history information

Blue shark has one of the widest ranges of all the shark species, being common in pelagic, oceanic waters in tropical and temperate oceans worldwide, as well as closer to shore (Coelho *et al.*, 2018). Various papers have reviewed the biology of blue shark (Nakano & Seki, 2003; da Silva *et al.*, 2021).

In a satellite telemetry study, Queiroz *et al.* (2010) described complex and diverse types of behaviour depending on water stratification and/or depth (Figure 8.6). Females tagged in the Western channel were able to spend up to 70 days in the shelf edge area in the Bay of Biscay; whereas tagged juveniles showed relatively extensive vertical movements away from the southern nursery areas. Results indicated that the species inhabited waters with a wide temperature range (10–20°C).

The US National Marine Fisheries Service also conducts a Cooperative Shark Tagging Programme (CSTP; Kohler *et al.*, 1998; NMFS, 2006), with tagging in the NE Atlantic also being undertaken under the auspices of the Inshore Fisheries Ireland (formerly the Irish Central Fishing Board) Tagging Programme (Green, 2007 WD) and UK Shark Tagging Programme, and there have been other earlier European tagging studies (e.g. Stevens, 1976). The tag and release results presented by ICCAT (2012; Figure 8.7) highlights the large number of blue shark tagged to date, and the extensive horizontal movements undertaken by blue shark in the Atlantic.

In Australian waters, blue shark exhibits oscillatory dive behaviour between the surface layers to as deep as 560–1000 m. Blue sharks mainly occupied waters of 17.5–20.0°C and spent 35–58% of their time in <50 m depths and 10–16% of their time >300 m (Stevens *et al.*, 2010). The distribution and movements of blue sharks are strongly influenced by seasonal variations in water temperature, reproductive condition and prey availability. Blue shark often occurs in large single-sex schools containing individuals of similar size.

Adult blue sharks have no known predators, although sub-adults and juveniles are eaten by shortfin mako, white shark and sea lions. Fishing is likely to be a major contributor to adult mortality. An estimation of fishing mortality rate via satellite tagged sharks being recaptured by fishing vessels ranged from 9–33% (Queiroz *et al.*, 2010).

Various studies have compiled biological information on this species in the North Atlantic and other areas, with some of these data summarized in Tables 8.4 (length–weight relationships), 8.3a and 8.3b (length–length relationships), Table 8.8 (growth parameters) and Table 8.9 (other life-history parameters). Based on life-history information, the blue shark is considered to be among the most productive shark species (ICCAT, 2008).

New life history inputs were obtained from data first assembled at the ICCAT 2014 Intersessional Meeting of the Shark Species Group (SCRS/2014/012) and additional information provided during the 2015 blue shark data preparatory meeting (SCRS/2015/142). These included maximum population growth rates (rmax) and steepness (h) values of the Beverton–Holt stock–recruitment relationship for North and South Atlantic stocks of blue shark, based on the latest biological information available gathered at the 2015 blue shark data preparatory meeting. To encompass a plausible range of values, uncertainty in the estimates of life history inputs (reproductive age, lifespan, fecundity, von Bertalanffy growth parameters, and natural mortality) was incorporated through Monte Carlo simulation by assigning statistical distributions to those biological traits in a Leslie matrix approach. Estimated productivity was high (rmax = 0.31–0.44 $y^{-1}$ for the North Atlantic stock), similar to other stocks of this species. Consequently, analytically derived values of steepness were also high (h = 0.73–0.93 for the North Atlantic stock).

The influence of different biological parameters (e.g. growth coefficients, reproductive periodicity, first maturation age, natural mortality and longevity) on estimated blue shark productivity was assessed. Age at first maturity and growth coefficients substantially influenced the estimated productivity (e.g. a low age at first maturity and high growth coefficient results in high productivity), and reproductive periodicity also affected productivity (i.e. a longer breeding period decreased productivity). Biological parameters should be carefully considered when they are used in the stock analysis, especially when estimated productivity is inconsistent with trends in abundance indices. The level of depletion experienced by blue shark stocks may affect the productivity or population growth through density dependence, and differences in environmental water temperature may also affect growth rates (Anon., 2015).

## 8.8 Exploratory assessment models

### 8.8.1 Previous assessments

In 2004, ICCAT completed a preliminary stock assessment (ICCAT, 2005). Although results suggested that the North Atlantic stock were above biomass in support of MSY, the assessment remained conditional on the assumptions made. These assumptions included (i) estimates of historical shark catch, (ii) the relationship between catch rates and abundance, (iii) the initial state of the stock in 1971, and (iv) various life-history parameters. It was pointed out that the data used for the assessment did not meet the requirements for proper assessment (ICCAT, 2006), and further research and better-resolved data collection was highly recommended.

In 2008, three models were used in stock assessment conducted by ICCAT (ICCAT, 2008 and references cited therein): a Bayesian surplus production model, an age-structured model that did not require catch data (catch-free model), and an age-structured production model. Results with the Bayesian surplus production model produced estimates of stock size well above MSY levels (1.5–2* $B_{MSY}$), and estimated F to be very low (at $F_{MSY}$ or well below it). The carrying capacity of the stock was estimated so high that the increasing estimated catches (25–62 000 t over the time-series) generated very low F estimates. Sensitivity analyses showed that the stock size estimate was dependent on the weighting assigned to the Irish CPUE series. Equal weighting of this and the other series produced a stock size at around $B_{MSY}$. Other sensitivity analyses indicated similar results to the base case run, with the stock well above MSY levels.

The age-structured biomass model displayed different results with either a strong decrease in biomass throughout the series to about 30% of virgin levels, or a less pronounced decline. The prior for the virgin biomass assigned high values to a very small number of biomass values but also indicated that the range of plausible values of this parameter has a heavy tail. This is probably because there is not enough information in the data to update the model and thus provide a narrower range of plausible values and thus provide a more precise estimate of the biomass of the stock.

The age-structured model not requiring catch information estimated that F was higher than $F_{MSY}$, but still low and that the current SSB estimated at around 83% of virgin levels.

As a consequence of the results in 2008, ICCAT concluded that biomass was estimated to be above the level that would support MSY (ICCAT, 2008). These results agreed with earlier work (ICCAT, 2005). Stock status appeared to be close to unfished biomass levels and fishing mortality rates were well below those corresponding to the level at which MSY is reached. However, ICCAT (2008) pointed out that the results were heavily dependent on the underlying assumptions. In particular, the choice of catch data to be used, the weighting of CPUE series and various life-history parameters used as input in the model. ICCAT was unable to conduct sensitivity analyses of the input data and assumptions (ICCAT, 2008).

Owing to those weaknesses, no firm conclusions were drawn from the preliminary assessments conducted by ICCAT. ICCAT, 2008 stated that most models used predicted that this stock was not overfished but did not use these results to infer stock status and to provide management advice.

## 8.9 Stock assessment

The North Atlantic Blue shark stock was assessed by ICCAT in 2015 using two different approaches (see ICCAT, 2015 for more details): Bayesian Surplus Production Model (BSPM) and length-based age-structured models - Stock Synthesis (SS3).

The Bayesian Surplus Production Models adjusted consistently estimated a posterior distribution for *r* that was similar to the prior, and a posterior for *K* with a long right tail with high mean and CV (ICCAT, 2015). The estimated biomass trajectory stayed close to *K* for most runs, and the harvest rate estimate was low (Figure 8.8). The inclusion of a process error in the model did not improve the results. When each CPUE index was fitted separately, the posterior mean of *K* varied and the CVs were large, implying that none of the indices were particularly informative about the value of *K*.

Several SS3 runs were undertaken. Run 4 and 6 (see details below) which utilized multiplication factors to reduce the input sample size assigned to length composition data in the model likelihood resulted in reasonable convergence diagnostics (described below).

| Model Run | Model Adjustments | | | | |
|---|---|---|---|---|---|
| Preliminary Run 1 | Natural weights used in model likelihood<br>Length composition input sample size (n = observed)<br>Abundance indices (inverse CV weighting: SCRS/2015/151 ) | | | | |
| Preliminary Run 2<br>CV adjustment | Same as Preliminary Run 1 + Adjust CV of S9 (ESP-LL-N)<br>Constant CV of 20% applied to S9 (ESP-LL-N) | | | | |
| Preliminary Run 3<br>Sample size adjustments | Same as Preliminary Run 2 + Adjust input sample size for length comp<br>Maximum length composition input sample size (n=200) | | | | |
| Preliminary Run 4 | Same as Preliminary Run 2 + Apply variance adjustment to length comp. | | | | |
| Fleet | F1 | F2 | F3 | F4 | F5 |
| Variance adjustments | 0.01 | 0.01 | 0.1 | 0.1 | 0.1 |
| Preliminary Run 5 | Same as Preliminary Run 2 + Apply variance adjustment to length comp. | | | | |
| Fleet | F1 | F2 | F3 | F4 | F5 |
| Variance adjustments | 0.0184 | 0.0478 | 0.0261 | 0.1373 | 0.2236 |
| Preliminary Run 6 | Same as Preliminary Run 2 + Apply variance adjustment to length comp. | | | | |
| Fleet | F1 | F2 | F3 | F4 | F5 |
| Variance adjustments | 0.0019 | 0.0047 | 0.0046 | 0.0573 | 0.0403 |

Model fits to CPUE and length composition data were similar for both runs. The fitting to abundance tracked trends well and were within most annual 95% confidence intervals for many abundance indices, including S3 (JPLL-N-e), S4 (JPLL-N-l), S6 (US-Obs-cru), S7 (POR-LL), and S9 (ESP-LL-N) (Figures 8.9–8.10). Model fits tracked trends reasonably well for abundance index S2 (US-Obs), but were often outside annual 95% confidence intervals. Predicted abundance was flat for abundance indices S8 (VEN-LL) and S10 (CTP-LL-N), probably because of large 95% confidence intervals for S8 and high inter-annual fluctuations in the early years for S10. Indices S1 (US-Log) and S5 (IRL-Rec) were only included in the model for exploratory purposes, were not fit in the model likelihood (lambda = 0), and had no influence on model results or predicted values. Model fits to length composition were reasonable for aggregate data (Figure 8.11).

Both run 4 and run 6 resulted in sustainable spawning stock size and fishing mortality rates relative to maximum sustainable yield (Figures 8.12–8.14). However, run 6 (the model run with relatively less weight applied to the length composition data in the model likelihood) resulted in a relatively more depleted stock size, compared to run 4.

Both models suggested sustainable spawning stock size and fishing mortality rates relative to maximum sustainable yield. The model with a relatively lower sample size assigned to the length composition data resulted in a relatively more depleted stock size. However, model fits to length composition were insufficient for annual length composition data, for which a bimodal pattern was evident. This is related to spatial segregation of the population. It was suggested that more work should be done to improve the fits to length composition data before using the model to provide management advice.

## 8.10 Quality of assessments

At the 2015 ICCAT assessment meeting, considerable progress was made on the integration of new data sources (in particular size data) and modelling approaches (in particular model structure). Uncertainty in data inputs and model configuration was explored through sensitivity analyses, which revealed that results were sensitive to structural assumptions of the models. The production models showed a poor fit to the flat or increasing trends in the CPUE series combined with increasing catches. Overall, assessment results are uncertain (e.g. level of absolute abundance varied by an order of magnitude between models with different structures) and should be interpreted with caution.

For the North Atlantic stock, scenarios with the BSPM estimated that the stock was not overfished ($B_{2013}/B_{MSY}$ = 1.50–1.96) and that overfishing was not occurring ($F_{2013}/F_{MSY}$ = 0.04–0.50). Estimates obtained with SS3 varied more widely, but still predicted that the stock was not overfished ($SSF_{2013}/SSF_{MSY}$ = 1.35–3.45) and that overfishing was not occurring ($F_{2013}/F_{MSY}$ = 0.15–0.75). Comparison of results obtained in the assessment conducted in 2008 and the current assessment revealed that, despite significant differences between inputs and models used, stock status results did not change drastically ($B_{2007}/B_{MSY}$ = 1.87–2.74 and $F_{2007}/F_{MSY}$ = 0.13–0.17 for the 2008 base runs using the BSP and a catch-free age-structured production model).

## 8.11 Reference points

ICCAT uses $F/F_{MSY}$ and $B/B_{MSY}$ as reference points for stock status of this stock. These reference points are relative metrics rather than absolute values. The absolute values of $B_{MSY}$ and $F_{MSY}$ depend on model assumptions and results and are not presented by ICCAT for advisory purposes.

## 8.12 Conservation considerations

The global IUCN listing for blue shark is Near Threatened (Rigby *et al.*, 2019), and it has the same listing in European waters, although is listed as Critically Endangered in the Mediterranean Sea (https://www.iucnredlist.org).

Blue shark was listed on Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) in 2017. However, it was not subsequently listed on Annex 1 of the Sharks-MoU.

## 8.13 Management considerations

Based on the scenarios and models explored, ICCAT considered the status of the North Atlantic stock as unlikely to be overfished nor subject to overfishing. However, due to the level of uncertainty, no specific management recommendations have been developed until 2017. Since 2017 Recommendation 16–12 is in place which states: "*If the average total catch of the North Atlantic blue shark in any consecutive two years from 2017 onward exceeds the average level observed during the period 2011–2015 (i.e. 39 102 t), the Commission shall review the implementation and effectiveness of these measures. Based on the review and the results of the next stock assessment scheduled for 2021 or at an earlier stage if enough information is provided to SCRS, the Commission shall consider introduction of additional measures*".

A further update in 2019 in Recommendation 19-07 is a follows: "*If in any year the total catches of the North Atlantic blue shark exceed the TAC, the Commission shall review the implementation of these measures. Based on the review and the results of the next stock assessment scheduled for 2021 or at an earlier stage if enough information is provided to the SCRS, the Commission shall consider introduction of additional measures*." In this same Recommendation (19-07) catch limits for the EU, Japan and Morocco were set.

Catch data are highly unreliable. Some CPUE series exist, and where data are available, show a relatively flat trend throughout the time-series, but with high variance. Further work is required to explain the trends and to better quantify removals from the stock.

Catch data are considered incomplete, and underestimated. There have been unaccounted discards and a substantial occurrence of finning over parts of the time series. Data reported to ICES, ICCAT and FAO can vary.

For accurate stock assessments of pelagic sharks, better fishery data are required. In addition, reporting procedures must be strengthened so that all landings are reported, and that landings are reported to species level, rather than generic "shark nei" categories. In the absence of reliable landings and catch data, catch ratios and market information derived from observers can provide useful information for understanding blue shark fishery dynamics.

For the North Atlantic stock, smaller sized blue sharks have been observed to dominate north of 30ºN, while larger sized blue sharks dominated south of 30ºN. In order to be able to account for the differences in size composition of fish in different areas, future implementations of SS3 should consider this spatial structure in the fleets. This will require estimating fleet and area specific CPUE indices, catch and size distributions. Ideally the model could also be separated by sex.

Blue shark is considered to be one of the most productive sharks in the North Atlantic. As such, it can be expected to be more resilient to fishing pressure than other pelagic sharks. However, the high degree of susceptibility to longline fishing and the poor quality of the information available to assess the stock is a cause for concern. Given the uncertainty of the results and that this species is a significant bycatch, especially in tuna and billfish fisheries, there is a need for continued monitoring of the fisheries by observer and port sampling programmes. There are currently no fishery-independent data available for that part of the stock in the ICES area.

## 8.14 References

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**Table 8.1. Blue shark in the North Atlantic. Landings (t) by country 1978–2018 from ICCAT Task I catch data (accessed June 2019). These are considered underestimates, especially prior to 1997.**

| Stock | Country | 1978 | 1979 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Atlantic | Belize | | | | | | | | | | | | | | | | | | | | | |
| | Brazil | | | | | | | | | | | | | | | | | | | | | |
| | Canada | | | | | | | | 320 | 147 | 968 | 978 | 680 | 774 | 1277 | 1702 | 1260 | 1494 | 528 | 831 | 612 | 547 |
| | Cape Verde | | | | | | | | | | | | | | | | + | | | | | |
| | China P.R. | | | | | | | | | | | | | | | | | | | | | |
| | Chinese Taipei | | | | | | | | | | | | | | | | | | | | | |
| | EU.Denmark | | | | | | | | | | | 2 | 2 | 1 | 1 | | 1 | 2 | 3 | 1 | 1 | |
| | EU.Spain | | | | | | | | | | | | | | | | | | | 24497 | 22504 | 21811 |
| | EU.France | 4 | 12 | | 9 | 8 | 14 | 39 | 50 | 67 | 91 | 79 | 130 | 187 | 276 | 322 | 350 | 266 | 278 | 213 | 163 | 399 |
| | EU.Ireland | | | | | | | | | | | | | | | | | | | | | 66 |
| | EU.Netherlands | | | | | | | | | | | | | | | | | | | | | |
| | EU.Portugal | | | | | | | | | | | | 1387 | 2257 | 1583 | 5726 | 4669 | 4722 | 4843 | 2630 | 2440 | 2227 |
| | EU.UK | | | | | | | | | | | | 1 | | | | + | 12 | | | 1 | + |
| | FR.St Pierre et Miquelon | | | | | | | | | | | | | | | | | | | | | |
| | Japan | | | | | | | | | | | | | | | | 1203 | 1145 | 618 | 489 | 340 | 357 |
| | Mexico | | | | | | | | | | | | | | | | | + | | | | |
| | Panama | | | | | | | | | | | | | | | | | | | | | 9 |
| | Senegal | | | | | | | | | | | | | | | | | | | | | |
| | Trinidad & Tobago | | | | | | | | | | | | | | | | | | | | | |
| | U.S.A. | | | 204 | | 605 | 107 | 341 | 1112 | 1400 | 776 | 751 | 829 | 1080 | 399 | 1816 | 601 | 641 | 987 | 391 | 447 | 317 |
| | UK.Bermuda | | | | | | | | | | | | | | | | | 3 | 1 | 1 | 2 | 8 |

| Stock | Country | 1978 | 1979 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Korea Rep. | | | | | | | | | | | | | | | | | | | | | |
| | Namibia | | | | | | | | | | | | | | | | | | | | | |
| | South Africa | | | | | | | | | | | | | | | | | | | | | |
| | Uruguay | | | | | | | | | | | | | | | | | | | | | |
| | Venezuela | | | | | | | | | | | | | | | | | | | | | |
| **N. Atlantic** | **Total** | **4** | **12** | **204** | **9** | **613** | **121** | **380** | **1482** | **1614** | **1835** | **1810** | **3028** | **4299** | **3536** | **9566** | **8084** | **8285** | **7258** | **29053** | **26510** | **25741** |
| Mediterra-nean | EU.Cyprus | | | | | | | | | | | | | | | | | | | | | |
| | EU.Spain | | | | | | | | | | | | | | | | | | | 146 | 59 | 20 |
| | EU.France | | | | | | | | | | | | | | | | | | | | | |
| | EU.Italy | | | | | | | | | | | | | | | | | | | | | |
| | EU.Malta | | | | | | | | | | | | | | | | 1 | 1 | 1 | + | + | + |
| | EU.Portugal | | | | | | | | | | | | | | | | | | | | 2 | |
| | Japan | | | | | | | | | | | | | | | | 5 | 7 | 1 | 1 | | |
| **Mediterra-nean** | **Total** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **+** | **5.581** | **8.376** | **1.768** | **147.95** | **60.856** | **20.445** |
| **N.ATL AND MED TOTAL** | | **4** | **12** | **204** | **9** | **613** | **121** | **380** | **1482** | **1614** | **1835** | **1810** | **3028** | **4299** | **3536** | **9566** | **8090** | **8293** | **7260** | **29201** | **26571** | **25761** |

**Table 8.1.** ***Cont*****. Blue shark in the North Atlantic. Landings (t) by country 1978–2018 from ICCAT Task I catch data (accessed June 2019). These are considered underestimates, especially prior to 1997.**

| | | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ATN | | 28174 | 21709 | 20066 | 22951 | 21742 | 22359 | 23217 | 26927 | 30723 | 35198 | 37178 | 38084 | 36786 | 37202 | 39881 | 39502 | 42029 |
| | ATS | | 12444 | 14043 | 12682 | 14967 | 14438 | 20642 | 20493 | 23487 | 23097 | 23459 | 27799 | 34926 | 26347 | 19545 | 29292 | 22172 | 23938 |
| | MED | | 45 | 47 | 17 | 11 | 125 | 72 | 178 | 50 | 81 | 185 | 216 | 40 | 42 | 100 | 235 | 85 | 79 |
| TOTAL | | | 40664 | 35800 | 32765 | 37928 | 36305 | 43072 | 43888 | 50464 | 53901 | 58842 | 65193 | 73050 | 63174 | 56848 | 69408 | 62012 | 66273 |
| Landings | ATN | Longline | 27305 | 20699 | 19290 | 22880 | 21297 | 22167 | 23067 | 26810 | 30514 | 35031 | 36952 | 37777 | 36549 | 36882 | 39677 | 38777 | 41772 |
| | | Other surf. | 732 | 905 | 708 | 70 | 380 | 126 | 104 | 63 | 80 | 63 | 59 | 100 | 109 | 74 | 205 | 725 | 257 |
| | ATS | Longline | 12444 | 14042 | 12678 | 14961 | 14339 | 20638 | 20434 | 23417 | 22708 | 23453 | 27785 | 34531 | 25878 | 19375 | 27457 | 21355 | 23309 |
| | | Other surf. | 0 | 1 | 4 | 6 | 99 | 3 | 59 | 10 | 375 | 6 | 14 | 391 | 264 | 0 | 1835 | 818 | 629 |
| | MED | Longline | 44 | 47 | 17 | 10 | 43 | 71 | 83 | 48 | 81 | 18 | 50 | 40 | 41 | 68 | 190 | 84 | 78 |
| | | Other surf. | 1 | 1 | 1 | 0 | 81 | 0 | 95 | 2 | 1 | 167 | 165 | 0 | 0 | 32 | 45 | 1 | 2 |
| Discards | ATN | Longline | 137 | 105 | 68 | 0 | 63 | 66 | 45 | 53 | 129 | 102 | 167 | 205 | 127 | 246 | 122 | 124 | 87 |
| | | Other surf. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 0 | | + | 0 |
| | ATS | Longline | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 14 | 0 | 0 | 4 | 206 | 169 | 114 | 122 | 139 |
| | | Other surf. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 6 | 0 |
| Landings | ATN | Barbados | | | | | | | | | | | | | | | | 9 | 6 |
| | | Belize | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 114 | 461 | 1039 | 903 | 1216 | | 4 | 6 |
| | | Brazil | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | | Canada | 624 | 1162 | 836 | 346 | 965 | 1134 | 977 | 843 | 0 | 0 | 0 | 0 | 1 | 0 | | 0 | 0 |
| | | Cape Verde | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | | China PR | 0 | 185 | 104 | 148 | 0 | 0 | 0 | 367 | 109 | 88 | 53 | 109 | 98 | 327 | | 1 | 27 |
| | | Chinese Taipei | 165 | 59 | 0 | 171 | 206 | 240 | 588 | 292 | 110 | 73 | 99 | 148 | 94 | 121 | 81 | 220 | 266 |
| | | EU.Denmark | 2 | 1 | 13 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | | EU.Spain | 24112 | 17362 | 15666 | 15975 | 17314 | 15006 | 15464 | 17038 | 20788 | 24465 | 26094 | 27988 | 28666 | 28562 | 25202 | 30078 | 29019 |
| | | EU.France | 395 | 207 | 221 | 57 | 106 | 120 | 99 | 167 | 119 | 84 | 122 | 115 | 31 | 216 | 129 | 259 | 352 |
| | | EU.Ireland | 31 | 66 | 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 | 1 | 0 | 0 |

| | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EU.Netherlands | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | EU.Portugal | 2081 | 2110 | 2265 | 5643 | 2025 | 4027 | 4338 | 5283 | 6167 | 6252 | 8261 | 6509 | 3768 | 3694 | 2913 | 3859 | 7819 |
| | EU.UKi | 12 | 9 | 6 | 4 | 6 | 5 | 3 | 6 | 6 | 96 | 8 | 10 | 8 | 10 | 10 | 12 | 17 |
| | FR.St Pierre et Miquelon | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | Japan | 273 | 350 | 386 | 558 | 1035 | 1729 | 1434 | 1921 | 2531 | 2007 | 1763 | 1227 | 2437 | 1808 | 2034 | 4011 | 4239 |
| | Korea Rep. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 537 | 299 | 327 | | 0 | 10 |
| | Marocco | | | | | | | | | | | | | | | | 873 | 0 |
| | Mexico | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | Panama | 0 | 0 | 0 | 0 | 0 | 0 | 254 | 892 | 613 | 1575 | 0 | 0 | 0 | 289 | | 0 | 0 |
| | Senegal | 0 | 0 | 456 | 0 | 0 | 0 | 0 | 43 | 134 | 255 | 56 | 0 | 5 | 12 | | 13 | 3 |
| | St.Vincent and Grenadines | | | | | | | | | | | | | | | | 0 | 119 |
| | Suriname | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 181 | 281 | | 0 | 0 |
| | Trinidad and Tobago | 0 | 0 | 6 | 3 | 2 | 1 | 1 | 0 | 2 | 8 | 9 | 11 | 11 | 8 | | 4 | 2 |
| | U.S.A. | 291 | 39 | 0 | 0 | 7 | 2 | 2 | 1 | 8 | 4 | 9 | 65 | 56 | 32 | | 31 | 30 |
| | UK.Bermuda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | Venezuela | 43 | 47 | 29 | 40 | 10 | 28 | 12 | 19 | 8 | 73 | 75 | 118 | 98 | 52 | | 129 | 116 |
| Discards ATN | Candada | | | | | | | | | | | | | | | | 0 | 0 |
| | Chinese Taipei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 14 | 9 | 5 | 16 |
| | Korea Rep. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 19 | 27 |
| | U.S.A. | 137 | 106 | 68 | 0 | 65 | 66 | 45 | 54 | 130 | 103 | 167 | 206 | 106 | 231 | | 18 | 1 |
| | UK.Bermuda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 82 | 43 |

**Table 8.2. Blue shark in the North Atlantic. Update for 2018 from SCRS (2019).**

| Component | Area | Fleet | 2017 | 2018 |
|---|---|---|---|---|
| Landings | ATN | Longline | 38509 | 32654 |
| | | Other surf. | 1033 | 1086 |
| | ATS | Longline | 27522 | 33546 |
| | | Other surf. | 487 | 664 |
| | MED | Longline | 92 | 54 |
| | | Other surf. | 13 | 4 |
| Discards | ATN | Longline | 133 | 112 |
| | | Other surf. | 0 | 0 |
| | ATS | Longline | 218 | 99 |
| | | Other surf. | 5 | 0 |
| Landings | ATN | Barbados | 7 | 4 |
| | | Belize | 201 | 317 |
| | | Brazil | 0 | 0 |
| | | Canada | 0 | 0 |
| | | Cape Verde | 0 | 0 |
| | | China PR | 2 | 6 |
| | | Chinese Taipei | | |
| | | EU.Denmark | 0 | 0 |
| | | EU.Spain | 27316 | 21685 |
| | | EU.France | 124 | 94 |
| | | EU.Ireland | 0 | 0 |
| | | EU.Netherlands | | 0 |
| | | EU.Portugal | 5664 | 5195 |
| | | EU.United Kingdom | 11 | 6 |
| | | FR.St Pierre et Miquelon | 0 | 0 |
| | | Japan | 4460 | 4111 |
| | | Korea Rep. | 103 | 92 |
| | | Marocco | 1475 | 1644 |
| | | Mexico | 0 | 0 |
| | | Panama | 0 | 437 |
| | | Senegal | 4 | 1 |
| | | St.Vincent and Grena- | | 0 |
| | | Suriname | | - |
| | | Trinidad and Tobago | 2 | 0 |
| | | U.S.A. | 24 | 19 |
| | | UK.Bermuda | 0 | 0 |
| | | Venezuela | 104 | |
| Discards | | Candada | 32 | 71 |
| | | Chinese Taipei | 34 | 31 |
| | | Korea Rep. | 29 | |
| | | U.S.A. | 38 | 11 |
| | | UK.Bermuda | | |
| Total | ATN | | 39675 | 33853 |
| | ATS | | 28232 | 34309 |
| | MED | | 105 | 58 |
| | Total | | 68011 | 68220 |

**Table 8.3. Blue shark in the North Atlantic. ICCAT Task I catch data by area for North Atlantic blue shark (accessed 15 June 2021, based on ICCAT data from 18/12/2020; data relate to landings and dead discards). Areas are Azores (AZOR), Canary Islands (CANA), Cape Verde (CVER), Gulf of Mexico (GOFM), Madeira Islands (MDRA), Northeast Atlantic (NE), North Atlantic (NORT), Northwest Atlantic (NW), Northwest Central Atlantic (NWC) and West Tropical Atlantic (WTRO).**

| Year | AZOR | CANA | CVER | GOFM | MDRA | NE | NORT | NW | NWC | WTRO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | | | | 1 | | 15363 | 203 | 1132 | 12547 | 40 | 29285 |
| 1998 | | | | | | 12410 | 246 | 1047 | 13051 | 10 | 26764 |
| 1999 | | | | 1 | | 11960 | 617 | 892 | 12654 | 48 | 26172 |
| 2000 | | | | 1 | | 11857 | 438 | 989 | 14844 | 44 | 28174 |
| 2001 | | | | 9 | | 10351 | 594 | 687 | 9440 | 47 | 21128 |
| 2002 | | | | 0 | | 9847 | 490 | 858 | 8835 | 35 | 20066 |
| 2003 | 639 | | | | | 9617 | 1208 | 359 | 11143 | 40 | 23006 |
| 2004 | 526 | | | | | 6423 | 1515 | 1020 | 12245 | 12 | 21741 |
| 2005 | 1485 | | 205 | 0 | 8 | 6378 | 1969 | 1160 | 11125 | 28 | 22359 |
| 2006 | 1203 | | 186 | | 28 | 6459 | 2022 | 1376 | 11931 | 12 | 23218 |
| 2007 | 1305 | | 259 | 0 | 12 | 6588 | 4189 | 1745 | 12810 | 20 | 26927 |
| 2008 | 981 | | 374 | 0 | 33 | 8794 | 5219 | 784 | 14530 | 10 | 30725 |
| 2009 | 2051 | 1 | 544 | 0 | 11 | 13363 | | 2058 | 17056 | 114 | 35199 |
| 2010 | 3221 | 47 | 971 | 0 | 34 | 12870 | | 938 | 19029 | 128 | 37239 |
| 2011 | 1287 | 4 | 774 | 0 | 18 | 10749 | | 2132 | 22939 | 189 | 38092 |
| 2012 | 293 | | 281 | 1 | | 13443 | | 1863 | 20707 | 195 | 36783 |
| 2013 | 110 | | | 0 | 0 | 13816 | | 1958 | 20850 | 353 | 37087 |
| 2014 | 26 | | | 1 | | 14159 | | 1052 | 21193 | 149 | 36579 |
| 2015 | 38 | | | 1 | | 18436 | | 318 | 20680 | 155 | 39627 |
| 2016 | 40 | | | 0 | 0 | 26260 | | 9269 | 8366 | 131 | 44068 |
| 2017 | 15 | | | 3 | 0 | 22308 | | 9876 | 7445 | 17 | 39664 |
| 2018 | 620 | | | 4 | | 17993 | | 8795 | 6576 | 6 | 33995 |
| 2019 | | | | 0 | 0 | 15994 | | 5872 | 5400 | 12 | 27279 |

**Table 8.4. Blue shark in the North Atlantic. Length–weight relationships for blue shark from different populations. Lengths in cm, and weights in kg unless specified in equation. $W_R$ = round weight; $W_D$ = dressed weight.**

| L (cm) W (kg) relationship | Sex | n | Length range (cm) | Source |
|---|---|---|---|---|
| $W_D$ = (8.04021 x 10–7) $L_F$ ^ 3.23189 | C | 354 | 75–250 ($L_F$) | García-Cortés and Mejuto, 2002 |
| $W_R$ = (3.1841 x 10–6) $L_F$ ^ 3.1313 | C | 4529 | | Castro, 1983 |
| $W_R$ = (3.92 x 10–6) LT ^ 3.41 | Male | 17 | | Stevens, 1975 |
| $W_R$ = (3.184 x 10–7) $L_T$ ^ 3.20 | Female | 450 | | Stevens, 1975 |
| $W_R$ = (3.2 x 10–6) $L_F$ ^ 3.128 | C | 720 | | Campana *et al.*, 2005 |
| $W_D$ = (1.7 x 10–6) $L_F$ ^ 3.205 | C | 382 | | Campana *et al.*, 2005 |

**Table 8.5(a). Blue shark in the North Atlantic. Length–length relationships for male, female blue shark and both sexes combined from the NE Atlantic and Straits of Gibraltar (Buencuerpo *et al.*, 1998). $L_S$ = standard length; $L_F$ = fork length; $L_T$ = total length; $L_{UC}$ = upper caudal lobe length.**

| Females | Males | Combined |
|---|---|---|
| $L_F$ = 1.076 $L_S$ + 1.862 (n = 1043) | $L_F$ = 1.080 $L_S$ + 1.552 (n = 1276) | $L_F$ = 1.079 $L_S$ + 1.668 (n = 2319) |
| $L_T$ = 1.249 $L_S$ + 7.476 (n = 1043) | $L_T$ = 1.272 $L_S$ + 4.466 (n = 1272) | $L_T$ = 1.262 $L_S$ + 5.746 (n = 2315) |
| $L_{UC}$ = 0.219 $L_S$ + 4.861 (n = 1038) | $L_{UC}$ = 0.316 $L_S$ + 2.191 (n = 1264) | $L_{UC}$ = 0.306 $L_S$ + 3.288 (n = 2302) |
| $L_T$ = 1.158 $L_F$ + 5.678 (n = 1043) | $L_T$ = 1.117 $L_F$ + 2.958 (n = 1272) | $L_T$ = 1.167 $L_F$ + 4.133 (n = 2315) |

**Table 8.5(b). Blue shark in the North Atlantic. Length–length relationships for both sexes combined of blue shark from various populations and sources.**

| Stock | Relationship | n | Source |
|---|---|---|---|
| NW Atlantic | $L_F$ = (0.8313) $L_T$ + 1.3908 | 572 | Kohler *et al.*, 1995 |
| NE Atlantic | $L_F$ = 0.8203 $L_T$ –1.061 | | Castro and Mejuto, 1995 |
| NW Atlantic | $L_F$ = –1.2 +0.842 $L_T$ | 792 | Campana *et al.*, 2005 |
| NW Atlantic | $L_T$ = 3.8 + 1.17 $L_F$ | 792 | Campana *et al.*, 2005 |
| NW Atlantic | $L_{CF}$ = 2.1 + 1.0 $L_{SF}$ | 782 | Campana *et al.*, 2005 |
| NW Atlantic | $L_{SF}$ = –0.8 + 0.98 $L_{CF}$ | 782 | Campana *et al.*, 2005 |
| NW Atlantic | $L_F$ = 23.4 + 3.50 $L_{ID}$ | 894 | Campana *et al.*, 2005 |
| NW Atlantic | $L_{ID}$ = –4.3 + 0.273 $L_F$ | 894 | Campana *et al.*, 2005 |

**Table 8.6. Blue shark in the North Atlantic. Indices of abundance for North and South Atlantic blue shark stocks. Source: ICCAT (2015).**

| | | | North Atlantic | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Usobs | JPLLe | JPLLI | USOLD | PORLL | VENLL | ESPLL | CHTPLL |
| 1957 | | | | 0.98 | | | | |
| 1958 | | | | 0.48 | | | | |
| 1959 | | | | 1.11 | | | | |
| 1960 | | | | 1.18 | | | | |
| 1961 | | | | 1.13 | | | | |
| 1962 | | | | 1.5 | | | | |
| 1963 | | | | 0.7 | | | | |
| 1964 | | | | 0.87 | | | | |
| 1965 | | | | 1.55 | | | | |
| 1966 | | | | 1.27 | | | | |
| 1967 | | | | 1.43 | | | | |
| 1968 | | | | 1.31 | | | | |
| 1969 | | | | 1.96 | | | | |
| 1970 | | | | 0.97 | | | | |
| 1971 | | 0.87 | | 1.08 | | | | |
| 1972 | | 1.46 | | 1.93 | | | | |
| 1973 | | 1.12 | | | | | | |
| 1974 | | 2.62 | | | | | | |
| 1975 | | 1.85 | | 0.88 | | | | |
| 1976 | | 1.07 | | 0.75 | | | | |
| 1977 | | 1.89 | | 1.82 | | | | |
| 1978 | | 1.58 | | 1.06 | | | | |
| 1979 | | 1.3 | | 0.860 | | | | |
| 1980 | | 2.21 | | 0.830 | | | | |
| 1981 | | 2.19 | | 1.050 | | | | |
| 1982 | | 2.08 | | 0.780 | | | | |
| 1983 | | 1.81 | | 1.010 | | | | |
| 1984 | | 1.22 | | 0.680 | | | | |
| 1985 | | 1.51 | | 0.740 | | | | |
| 1986 | | 1.52 | | 0.480 | | | | |
| 1987 | | 2.13 | | 0.500 | | | | |
| 1988 | | 1.21 | | 0.440 | | | | |
| 1989 | | 1.51 | | 0.800 | | | | |
| 1990 | | 1.34 | | 0.940 | | | | |
| 1991 | | 1.26 | | 1.220 | | | | |
| 1992 | 7.455 | 1.9 | | 0.63 | | | | |
| 1993 | 11.076 | 2.43 | | 0.95 | | | | |
| 1994 | 9.717 | | 2.33 | 0.98 | | 0.047 | | |
| 1995 | 10.17 | | 2.1 | 0.73 | | 0.073 | | |
| 1996 | 8.208 | | 2.05 | 0.47 | | 0.017 | | |
| 1997 | 14.439 | | 2.05 | 1.25 | 158.14 | 0.154 | 156.83 | |
| 1998 | 18.408 | | 1.72 | 1.16 | 169.02 | 0.216 | 154.45 | |
| 1999 | 6.663 | | 1.89 | 0.76 | 149.83 | 0.117 | 179.91 | |
| 2000 | 9.541 | | 1.58 | 0.78 | 201.44 | 0.151 | 213.05 | |
| 2001 | 2.306 | | 1.71 | | 222.14 | 0.133 | 215.63 | |
| 2002 | 2.277 | | 1.37 | | 200.86 | 0.074 | 183.94 | |
| 2003 | 1.876 | | 1.97 | | 238.77 | 0.044 | 222.88 | |
| 2004 | 9.503 | | 1.79 | | 266.16 | 0.034 | 177.27 | 0.749 |
| 2005 | 3.193 | | 1.9 | | 218.55 | 0.006 | 166.82 | 2.195 |
| 2006 | 4.674 | | 2.16 | | 212.63 | 0.013 | 177.11 | 1.308 |
| 2007 | 9.645 | | 2.18 | | 241.32 | 0.060 | 187.06 | 0.561 |
| 2008 | 8.512 | | 2.48 | | 225.68 | 0.088 | 215.80 | 0.495 |
| 2009 | 8.322 | | 2.46 | | 228.30 | 0.045 | 196.08 | 0.570 |
| 2010 | 13.545 | | 2.45 | | 276.76 | 0.040 | 209.03 | 0.877 |
| 2011 | 21.806 | | 2.37 | | 233.29 | 0.044 | 221.13 | 0.765 |
| 2012 | 8.128 | | 2.6 | | 305.53 | 0.107 | 238.00 | 0.668 |
| 2013 | 7.374 | | 2.09 | | 304.08 | 0.044 | 203.49 | 1.045 |

**Table 8.7. Blue shark in the North Atlantic. Coefficients of variation (CVs) for North and South Atlantic blue shark stocks. Source: ICCAT (2015).**

| | | North Atlantic | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Usobs | JPLLe | JPLLl | USOLD | PORLL | VENLL | ESPLL | CHTPLL |
| 1957 | | | | 0.17 | | | | |
| 1958 | | | | 0.16 | | | | |
| 1959 | | | | 0.25 | | | | |
| 1960 | | | | 0.38 | | | | |
| 1961 | | | | 0.35 | | | | |
| 1962 | | | | 0.27 | | | | |
| 1963 | | | | 0.25 | | | | |
| 1964 | | | | 0.17 | | | | |
| 1965 | | | | 0.17 | | | | |
| 1966 | | | | 0.23 | | | | |
| 1967 | | | | 0.21 | | | | |
| 1968 | | | | 0.21 | | | | |
| 1969 | | | | 0.22 | | | | |
| 1970 | | | | 0.32 | | | | |
| 1971 | | 0.53 | | 0.23 | | | | |
| 1972 | | 0.39 | | 0.21 | | | | |
| 1973 | | 0.45 | | | | | | |
| 1974 | | 0.32 | | | | | | |
| 1975 | | 0.34 | | 0.19 | | | | |
| 1976 | | 0.47 | | 0.29 | | | | |
| 1977 | | 0.27 | | 0.2 | | | | |
| 1978 | | 0.32 | | 0.11 | | | | |
| 1979 | | 0.24 | | 0.11 | | | | |
| 1980 | | 0.29 | | 0.09 | | | | |
| 1981 | | 0.36 | | 0.09 | | | | |
| 1982 | | 0.36 | | 0.09 | | | | |
| 1983 | | 0.37 | | 0.1 | | | | |
| 1984 | | 0.50 | | 0.1 | | | | |
| 1985 | | 0.44 | | 0.1 | | | | |
| 1986 | | 0.39 | | 0.09 | | | | |
| 1987 | | 0.35 | | 0.1 | | | | |
| 1988 | | 0.49 | | 0.12 | | | | |
| 1989 | | 0.44 | | 0.39 | | | | |
| 1990 | | 0.49 | | 0.17 | | | | |
| 1991 | | 0.47 | | 0.11 | | | | |
| 1992 | 0.31 | 0.43 | | 0.1 | | | | |
| 1993 | 0.29 | 0.40 | | 0.09 | | | | |
| 1994 | 0.29 | | 0.50 | 0.1 | | 1.08 | | |
| 1995 | 0.29 | | 0.55 | 0.1 | | 0.87 | | |
| 1996 | 0.50 | | 0.51 | 0.3 | | 1.90 | | |
| 1997 | 0.33 | | 0.52 | 0.13 | 0.084 | ` | 0.008 | |
| 1998 | 0.35 | | 0.53 | 0.15 | 0.076 | 0.67 | 0.008 | |
| 1999 | 0.34 | | 0.49 | 0.13 | 0.077 | 0.84 | 0.008 | |
| 2000 | 0.32 | | 0.28 | 0.12 | 0.083 | 0.74 | 0.008 | |
| 2001 | 0.39 | | 0.56 | | 0.089 | 0.77 | 0.008 | |
| 2002 | 0.39 | | 0.62 | | 0.086 | 1.03 | 0.008 | |
| 2003 | 0.37 | | 0.59 | | 0.082 | 1.26 | 0.009 | |
| 2004 | 0.30 | | 0.69 | | 0.084 | 1.53 | 0.009 | 0.12 |
| 2005 | 0.35 | | 0.71 | | 0.087 | 3.88 | 0.010 | 0.19 |
| 2006 | 0.31 | | 0.69 | | 0.084 | 2.24 | 0.010 | 0.06 |
| 2007 | 0.32 | | 0.61 | | 0.085 | 1.35 | 0.011 | 0.22 |
| 2008 | 0.32 | | 0.69 | | 0.085 | 1.16 | 0.011 | 0.28 |
| 2009 | 0.31 | | 0.64 | | 0.086 | 1.56 | 0.012 | 0.17 |
| 2010 | 0.31 | | 0.64 | | 0.089 | 1.54 | 0.010 | 0.10 |
| 2011 | 0.29 | | 0.51 | | 0.079 | 1.51 | 0.010 | 0.12 |
| 2012 | 0.34 | | 0.51 | | 0.081 | 1.00 | 0.010 | 0.11 |
| 2013 | 0.31 | | 0.21 | | 0.085 | 1.84 | 0.011 | 0.14 |

**Table 8.8. Blue shark in the North Atlantic. Von Bertalanffy growth parameters (L∞ in cm ($L_T$), k in years$^{-1}$, t0 in years) from published studies.**

| Area | L∞ | k | t0 | Sex | Study |
|---|---|---|---|---|---|
| North Atlantic | 394 | 0.133 | –0.801 | Combined | Aasen, 1966 |
| North Atlantic | 423 | 0,11 | –1.035 | Combined | Stevens, 1975 |
| NW Atlantic | 343 | 0.16 | –0.89 | Males | Skomal, 1990 |
| NW Atlantic | 375 | 0.15 | –0.87 | Females | Skomal, 1990 |
| NE Atlantic | 377 | 0.12 | –1.33 | Combined | Henderson *et al.*, 2001 |
| North Atlantic | 282 | 0.18 | –1.35 | Males | Skomal and Natanson, 2002 |
| North Atlantic | 310 | 0.13 | –177 | Females | Skomal and Natanson, 2002 |
| North Atlantic | 287 | 0.17 | –1.43 | Combined | Skomal and Natanson, 2003 |
| NW Atlantic | 300 | 0.68 | –0.25 | Combined | MacNeil and Campana, 2002 (whole ages) |
| NW Atlantic | 302 | 0.58 | –0.24 | Combined | MacNeil and Campana, 2002 (section ages) |

**Table 8.9. Blue shark in the North Atlantic. Biological parameters for blue shark.**

| Parameter | Values | Sample Size | Area | Reference |
|---|---|---|---|---|
| Reproduction | Placental viviparity | | | various |
| Litter size | 25–50 (30 average) | | | various |
| Size-at-birth | 30–50 cm LT | | | Various |
| Sex ratio (males: females) | 1.5:1 | | NE Atlantic | García-Cortés and Mejuto, 2002 |
| | 1:1.44 | | NE Atlantic | Henderson *et al.*, 2001 |
| | 1.33:1 | | NW Atlantic | Kohler *et al.*, 2002 |
| | 1:2.13 | | NE Atlantic | Kohler *et al.*, 2002 |
| | 1:1.07 | 801 | NE Atlantic (N. coast Spain) | Mejuto and García-Cortés, 2005 |
| | 1:0.9 | 158 | NE Atlantic (S. coast Spain) | |
| | 1:0.38 | 2187 | N central Atlantic | |
| | 1:0.53 | 4550 | NW Atlantic | |
| Gestation period | 9–12 months | | | Campana *et al.*, 2002 |
| % of females revealing fecundation signs | 0.74 | 415 | NE Atlantic (N. coast Spain) | Mejuto and García-Cortés, 2005 |
| | 0 | 76 | NE Atlantic (S. coast Spain) | |
| | 36.27 | 601 | N central Atlantic | |
| | 18.15 | 1573 | NW Atlantic | |
| % of pregnant females | 0 | 415 | NE Atlantic (N. coast Spain) | Mejuto and García-Cortés, 2005 |
| | 0 | 76 | NE Atlantic (S. coast Spain) | |
| | 14.6 | 601 | N central Atlantic | |
| | 9.8 | 1573 | NW Atlantic | |

| Parameter | Values | Sample Size | Area | Reference |
|---|---|---|---|---|
| Male age-at-maturity (years) | 4–6 | | | various |
| Female age-at-maturity (years) | 5–7 | | | various |
| Male length-at-maturity | 180–280 cm (LF) | | NW Atlantic | Campana *et al*., 2002 |
| | 190–195 cm (LF) | | | Francis and Duffy, 2005 |
| | 201 cm (LF; 50% maturity) | | NW Atlantic | Campana *et al*., 2005 |
| Female length-at-maturity | 220–320 cm (LF) | | | Campana *et al*., 2002 |
| | 170–190 cm (LF) | | | Francis and Duffy, 2005 |
| | > 185 cm (LF) | | | Pratt, 1979 |
| Longevity (years) | 16–20 | | | Skomal and Natanson, 2003 |
| Natural mortality (M) | 0.23 | | Worldwide | Campana *et al*., 2005 (mean of various studies) |
| Productivity (R2m) estimate: intrinsic rebound | 0.061 (assuming no fecundity increase) | | Pacific | Smith *et al*., 1998 |
| Potential rate of increase per year | 43% (unfished) | | NW Atlantic | Campana *et al*., 2005 |
| Population doubling time TD (years) | 11.4 (assuming no fecundity increase) | | Pacific | Smith *et al*., 1998 |
| Trophic level | 4.1 | 14 | | Cortés, 1999 |

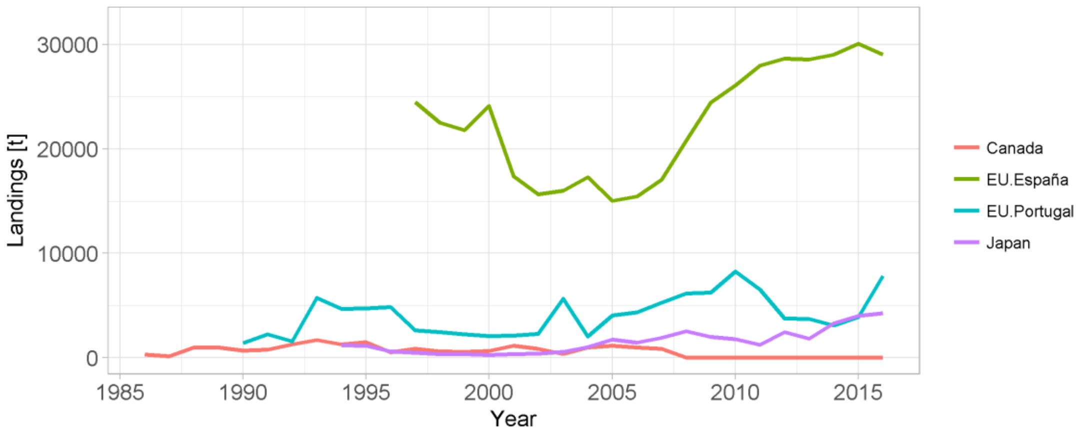



**Figure 8.1. Blue shark in the North Atlantic. Preliminary estimates of landings of blue shark in the Atlantic for the four main countries (Source: ICCAT Task I data, Accessed June 2018).**

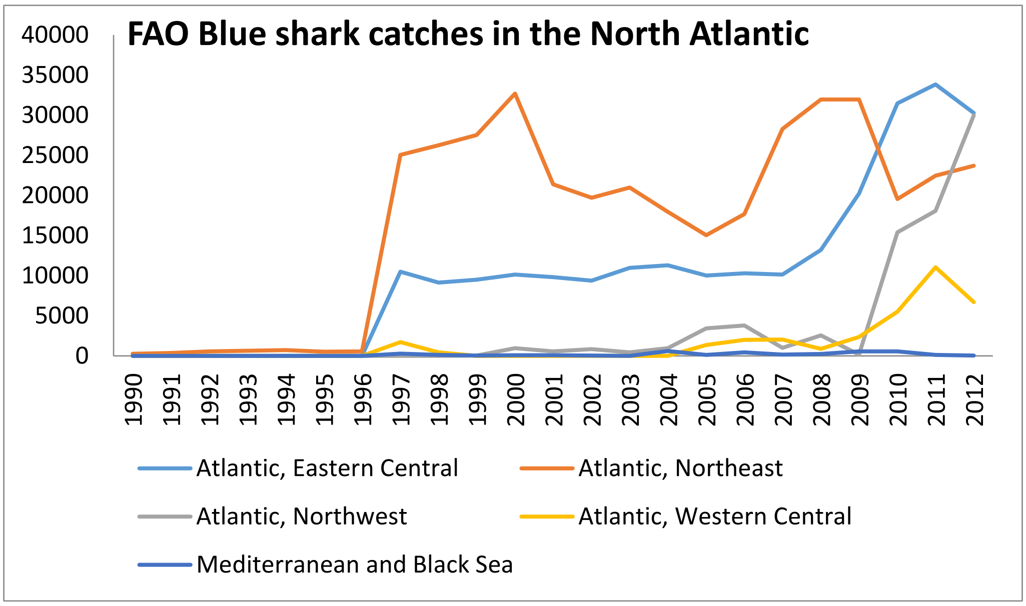



**Figure 8.2. Blue shark in the North Atlantic. Preliminary estimates of landings of blue shark in the Atlantic Ocean for the different areas (Source: FAO, 2014).**

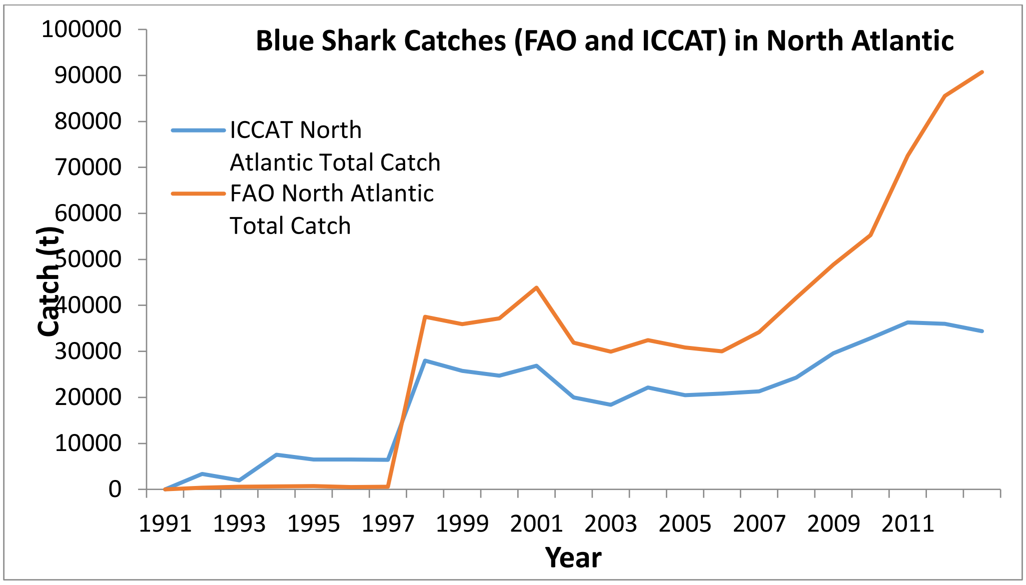
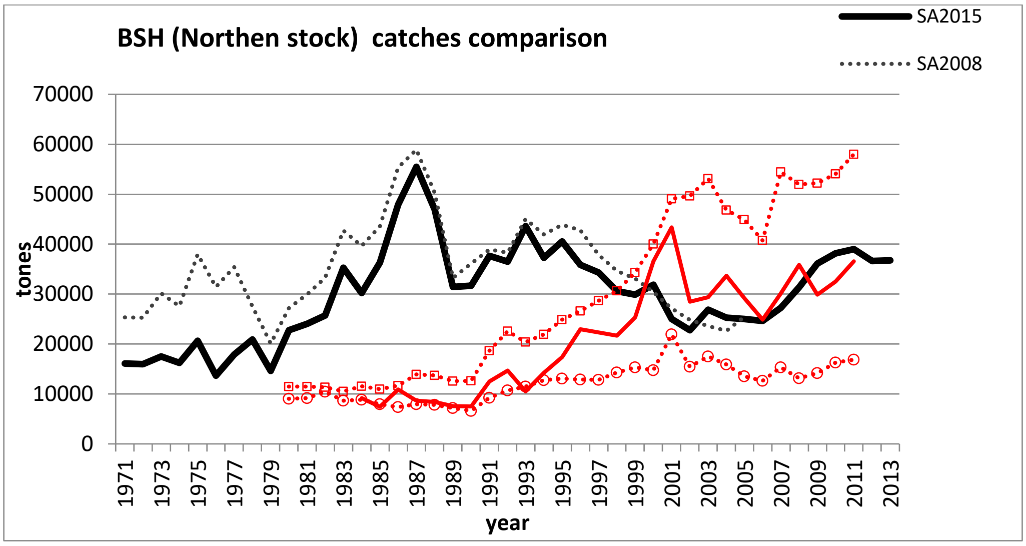



**Figure 8.3. Blue shark in the North Atlantic. Blue shark catches in the North Atlantic from FAO and ICCAT data (1990–2013) illustrating the difference between data sources.**



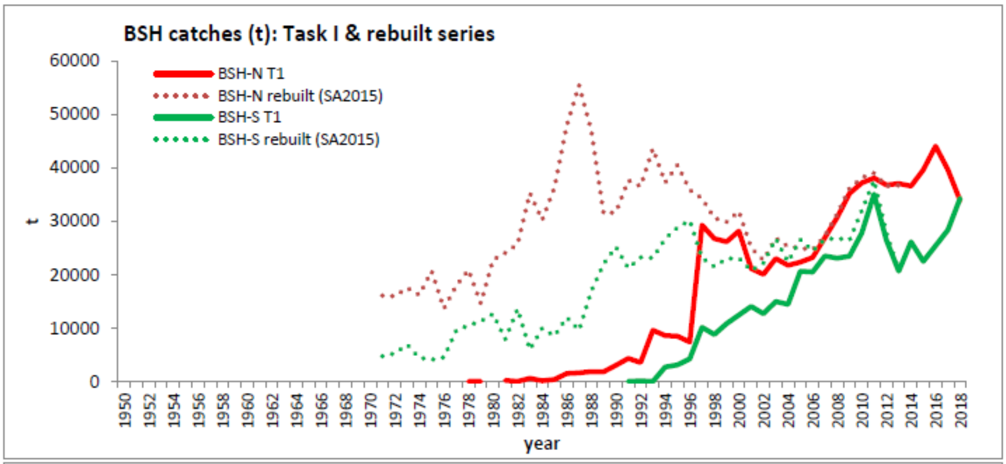




**Figure 8.4. Top. Blue shark in the North Atlantic. Comparison of various catch series for the North Atlantic stock of blue shark (1971–2013). In black, the stock assessment catches from the 2008 stock assessment (dotted line) and 2015 estimations (solid line). In red, three catch series obtained using shark-fin ratios with three different approaches (area, effort, target level). Bottom: Update of catches reported to ICCAT (Task I) and estimated by SCRS (SCRS, 2019). Dotted lines are values from the 2008 assessment, solid line those of the 2015 estimates.**

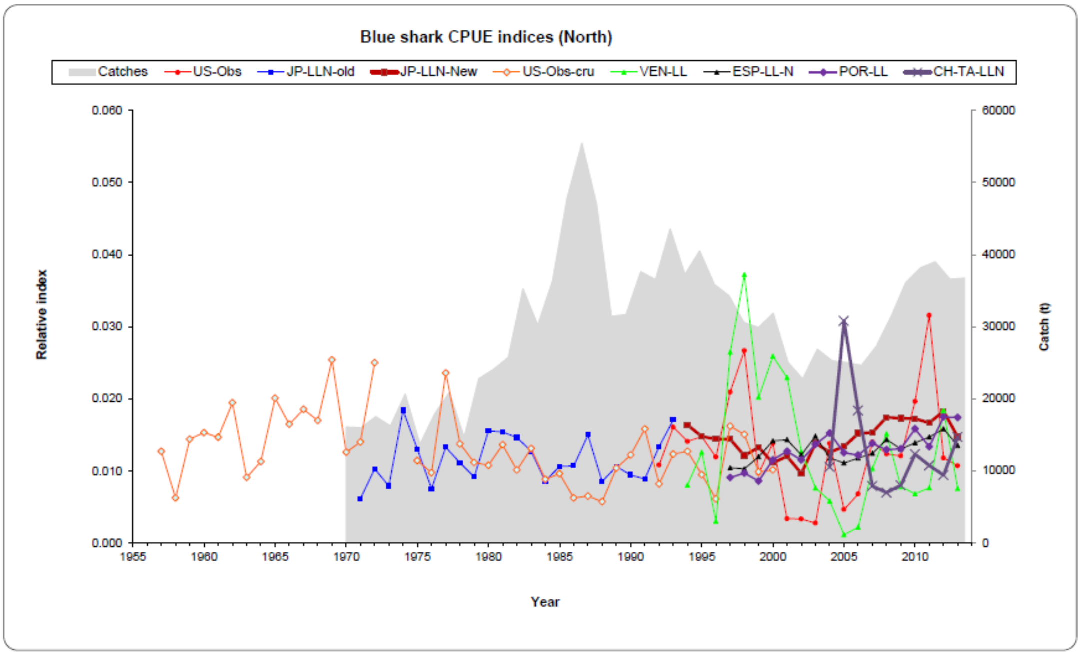



Figure 8.5. Blue shark in the North Atlantic. Indices of abundance and catches. Source: ICCAT (2019).

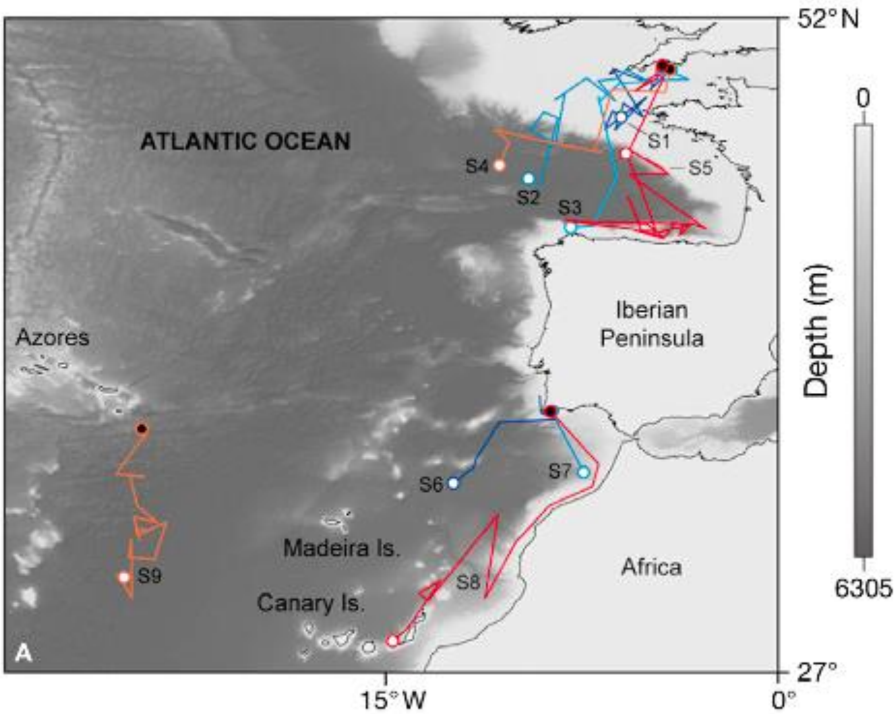



Figure 8.6. Blue shark in the North Atlantic. Pop-off satellite-tagged blue shark movement patterns. (A) General movements overlaid on bathymetry; black circles denote tagging locations and white circles the pop-up/capture locations. (B to J) Individual tracks overlaid on sea surface temperature maps; white circles are geolocated positions with date. Source: Queiroz *et al.* (2010).

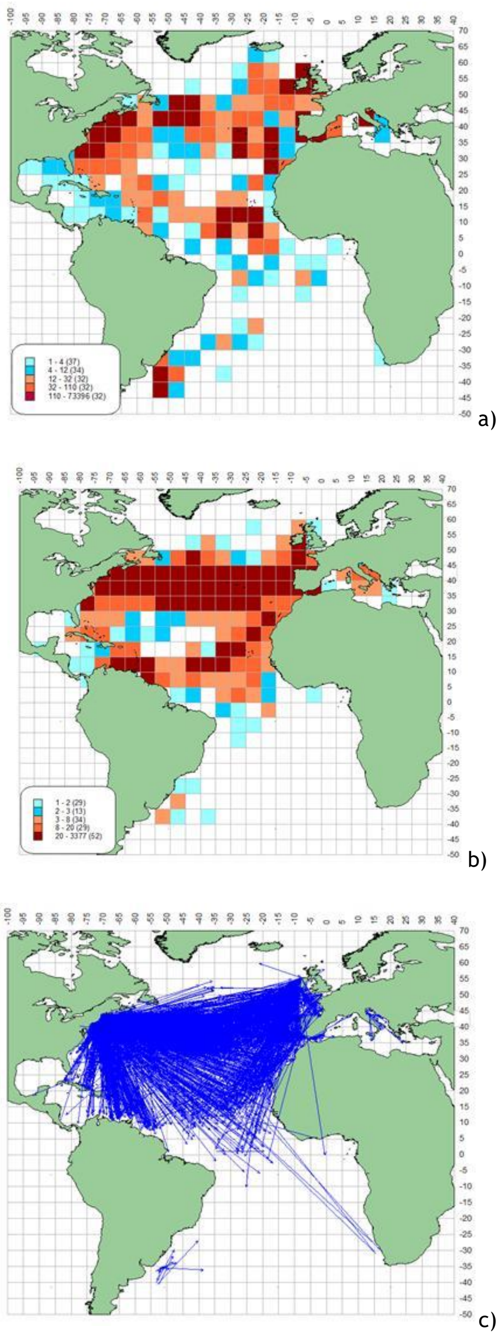



**Figure 8.7. Blue shark in the North Atlantic. Blue shark tagging maps, presented by ICCAT (2012), showing (a) density of releases, (b) density of recoveries, and (c) straight line displacement between release and recovery locations.**

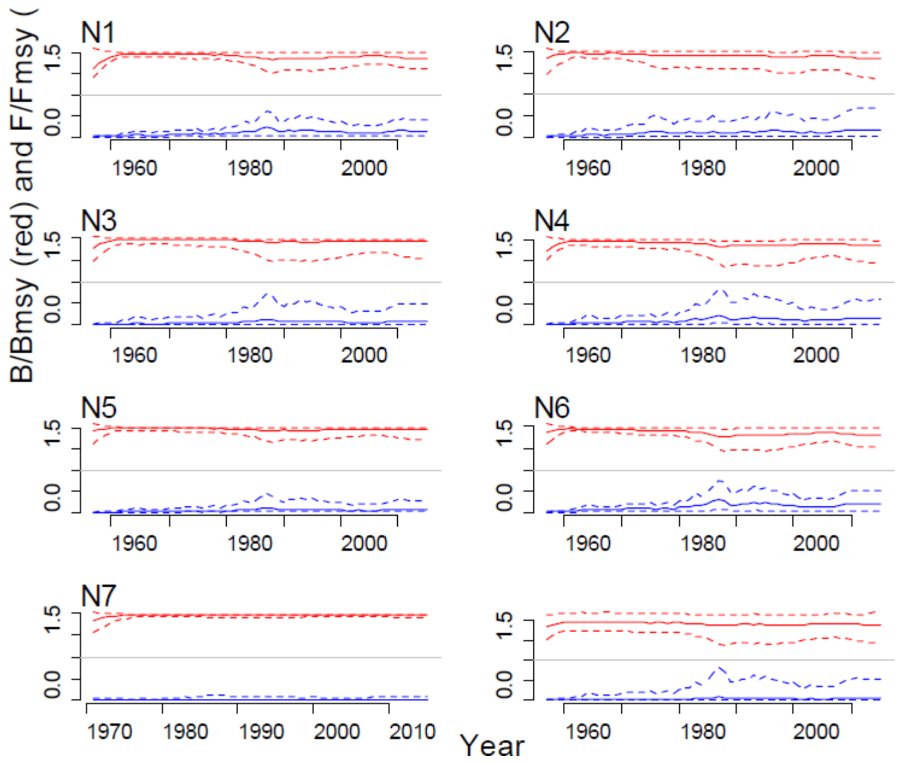



**Figure 8.8. Blue shark in the North Atlantic. Estimated biomass relative to $B_{MSY}$ (in red) and harvest rate relative to the MSY level (blue), for the BSP runs. Source: ICCAT (2015).**

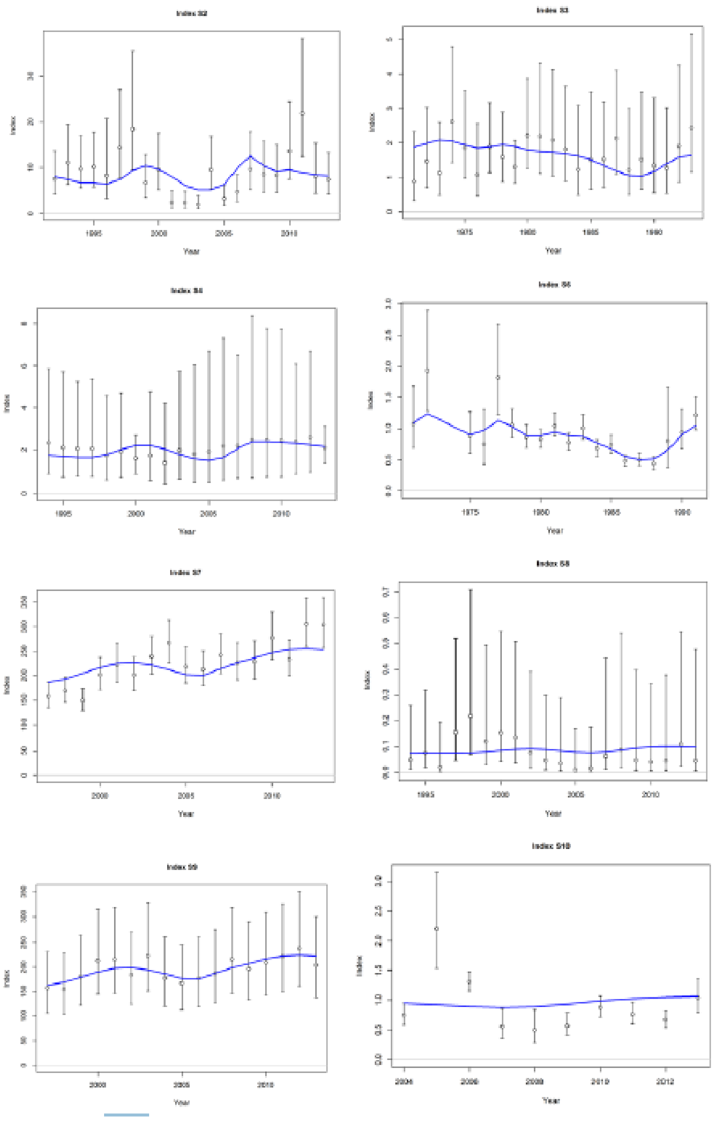


**Figure 8.9. Blue shark in the North Atlantic. Preliminary Run 4 observed CPUE (open circles ± 95% confidence intervals assuming lognormal error) and model predicted CPUE (blue line) for abundance indices fit in the model likelihood: S2 (US-Obs, upper left), S3 (JPLL-N-e, upper right), S4 (JPLL-N-l, middle left), S6 (US-Obs-cru, middle right), S7 (POR-LL, middle left), S8 (VEN-LL, middle right), S9 (ESP-LL-N, lower left), and S10 (CTP-LL-N, lower right). Source: ICCAT (2015).**

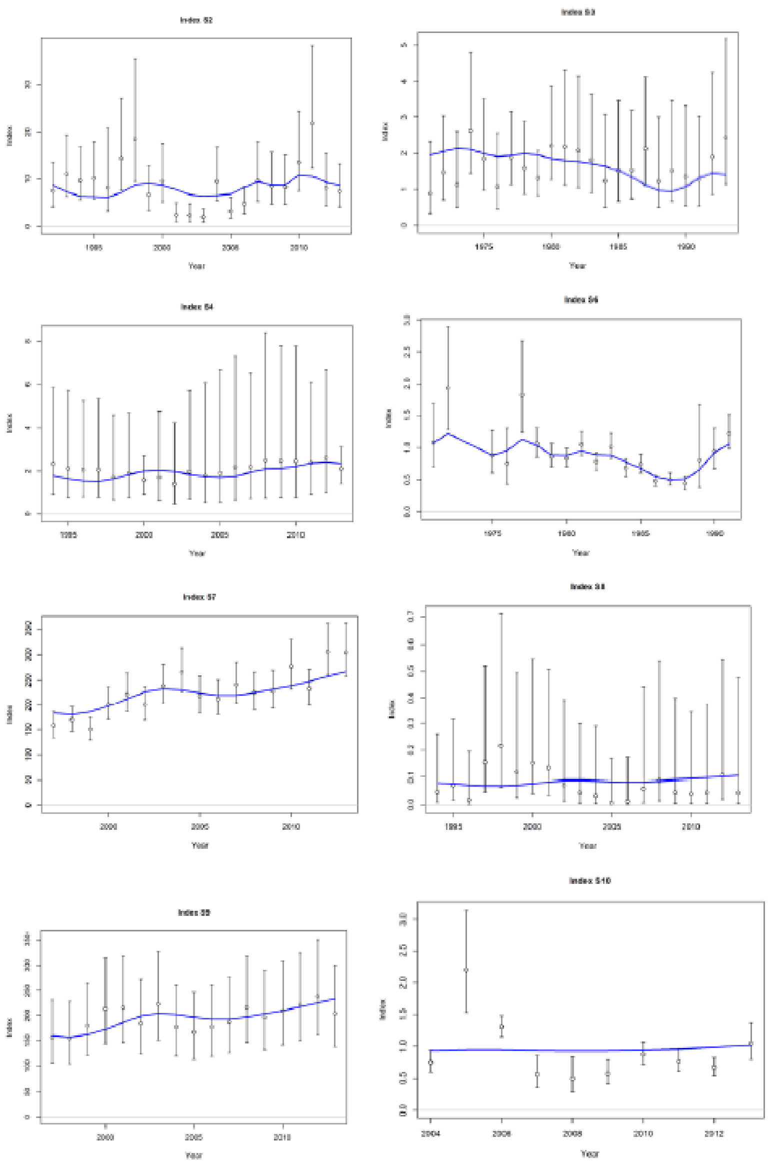



**Figure 8.10. Blue shark in the North Atlantic. Preliminary Run 6 observed CPUE (open circles ± 95% confidence intervals assuming lognormal error) and model predicted CPUE (blue line) for abundance indices fit in the model likelihood: S2 (US-Obs, upper left), S3 (JPLL-N-e, upper right), S4 (JPLL-N-l, middle left), S6 (US-Obs-cru, middle right), S7 (POR-LL, middle left), S8 (VEN-LL, middle right), S9 (ESP-LL-N, lower left), and S10 (CTP-LL-N, lower right). Source: ICCAT (2015).**

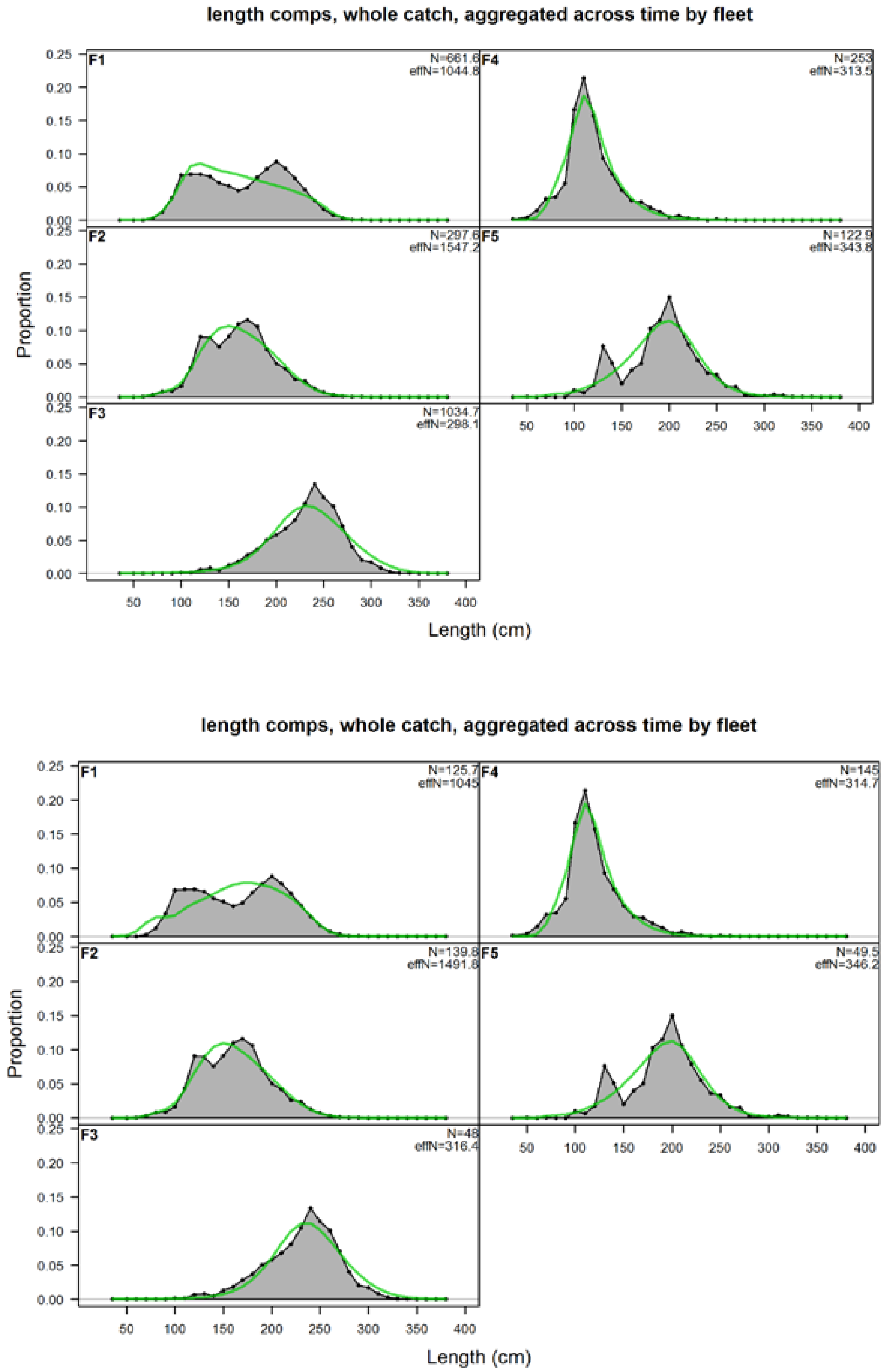



**Figure 8.11. Blue shark in the North Atlantic. Model predicted (line) and observed (shaded) aggregated annual length compositions (female + male) for Preliminary Run 4 (upper panel) and Preliminary Run 6 (lower panel). Source: ICCAT (2015).**

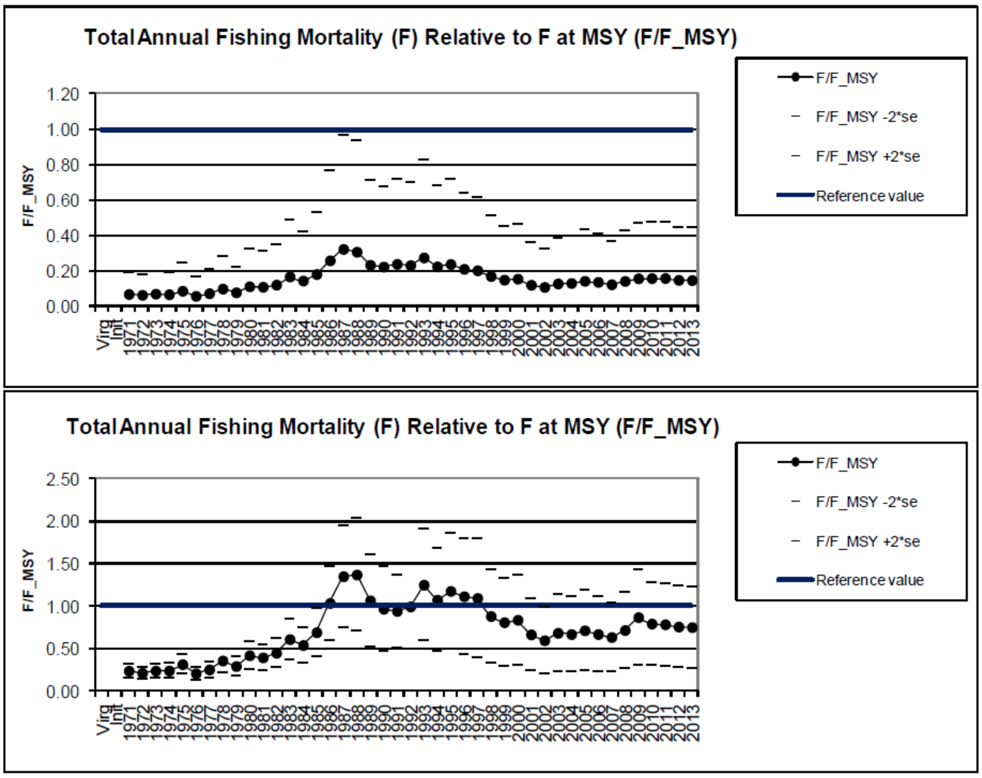



**Figure 8.12. Blue shark in the North Atlantic. Estimated annual total exploitation rate in numbers (total fishing mortality for all fleets combined) relative to fishing mortality at MSY ($F/F_{MSY}$), obtained from Stock Synthesis output for Preliminary Run 4 (upper panel) and Preliminary Run 6 (lower panel). Source: ICCAT (2015).**

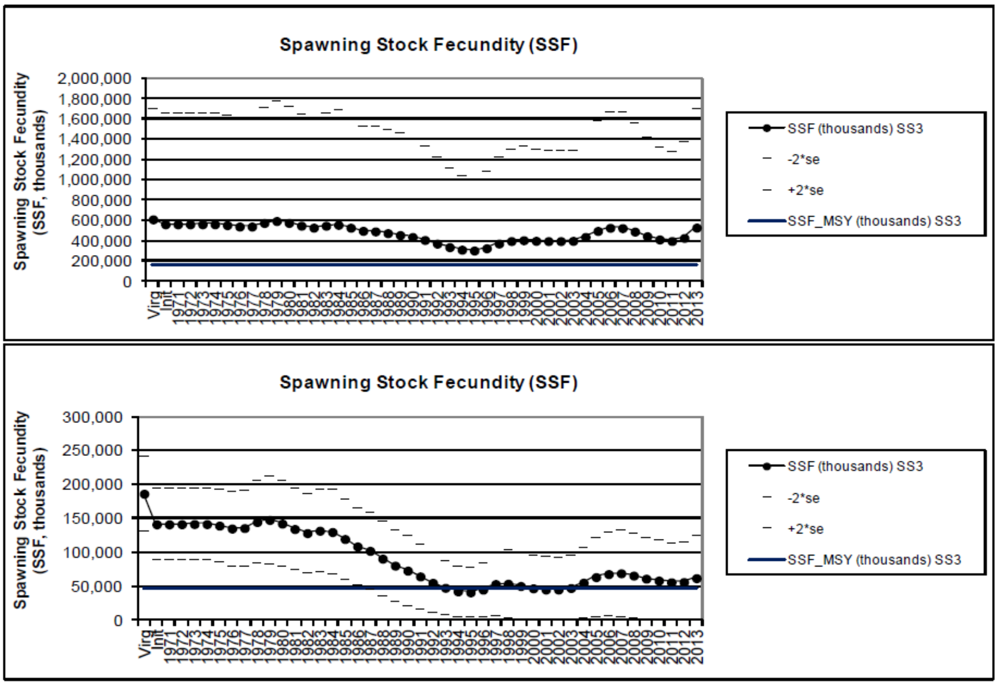



**Figure 8.13. Blue shark in the North Atlantic. Estimated spawning stock size (spawning stock fecundity, SSF) along with approximate 95% asymptotic standard errors (±2*s.e.) relative to spawning stock size at MSY (SSFMSY) for Preliminary Run 4 (upper panel) and Preliminary Run 6 (lower panel). Source: ICCAT (2015).**

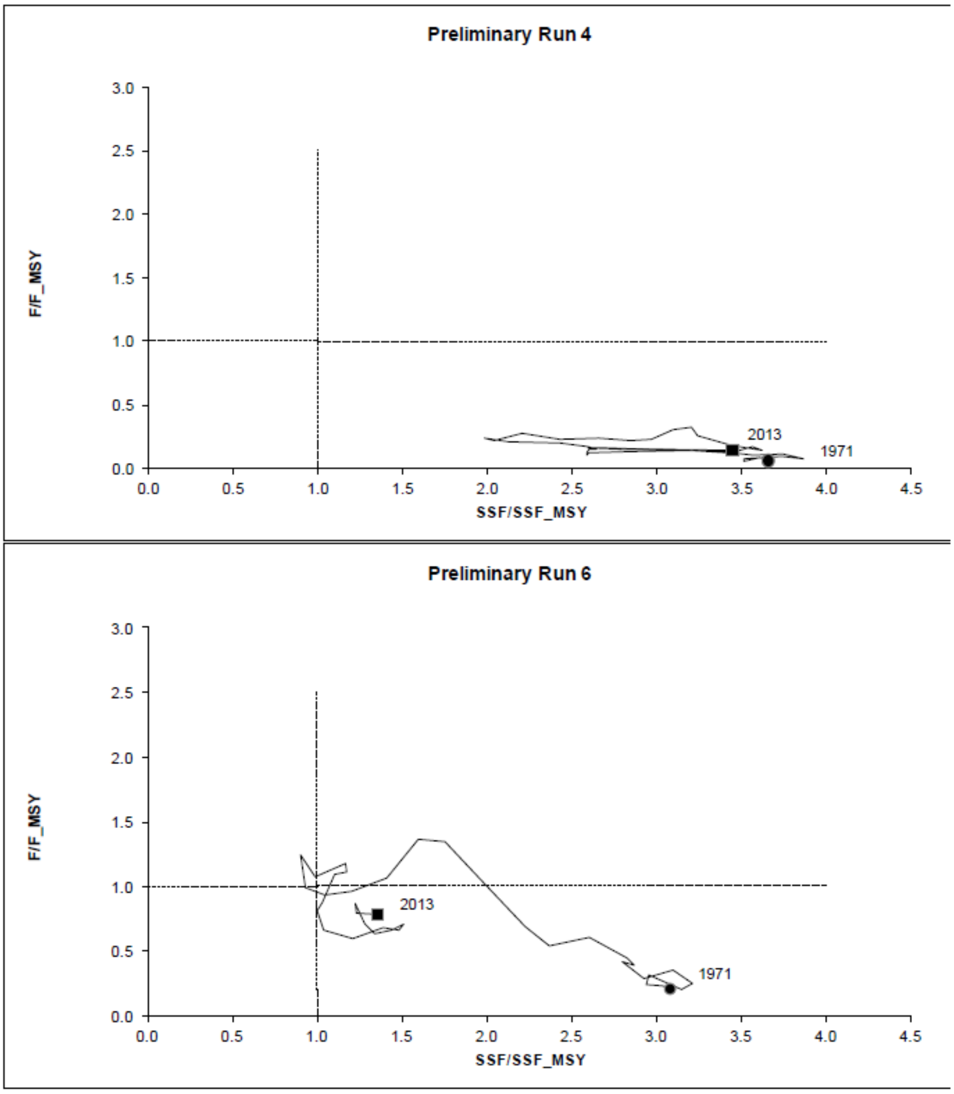



**Figure 8.14. Blue shark in the North Atlantic. Kobe Phase plots for Preliminary Run 4 (upper panel) and Preliminary Run 6 (lower panel). The circle indicates the position of the start year of the model (1971) and the square represents the end year of the model (2013). The horizontal (dotted) line identifies the fishing mortality reference at maximum sustainable yield ($F_{MSY}$). The vertical (dotted) line identifies the reference spawning stock fecundity at maximum sustainable yield ($SSF_{MSY}$). Source: ICCAT (2015).**